Atmospheric Railway

Sir J. M. F. Smith

Smith (Sir F.) and Barlow (P).

Report
on the
Atmospheric Railway

1842.

REPORT

OF

LIEUT.-COLONEL SIR John Mark FREDERIC SMITH,

ROYAL ENGINEERS,

AND

PROFESSOR BARLOW,

TO THE RIGHT HONOURABLE THE EARL OF RIPON,
PRESIDENT OF THE BOARD OF TRADE,

ON THE

ATMOSPHERIC RAILWAY.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, STAMFORD STREET,
FOR HER MAJESTY'S STATIONERY OFFICE.

1842.

CONTENTS.

REPORT.

Board of Trade, Whitehall.
February 15, 1842.

My Lord,

In compliance with your Lordship's desire, we have the honour to report the results of our inquiry into the application of the atmospheric principle in producing locomotion on railways.

As Mr. Pim, the treasurer of the Dublin and Kingstown Railway, in his letter addressed to your Lordship soliciting this investigation, has correctly described the means adopted for producing the propelling power,* it is unnecessary for us to repeat that description; we may proceed therefore at once to state the result of our inquiries as to the utility of carrying into effect this novel system of locomotion.

The experiments which have been tried at Wormwood Scrubs have proved the practicability of giving motion to considerable loads at a maximum velocity of 40 miles per hour.

On the 8th August, 1840, we were present at experiments, when a load of 13 tons was thus propelled, and a mean velocity obtained in the first experiment of 20 miles per hour, and in the second experiment of between 19 and 20 miles per hour.

On the 12th and 14th January, 1842, in accordance with your Lordship's instructions, we instituted certain other experiments, when the maximum velocity obtained with a load of five tons was, in one set of experiments, 26, and in the other set 40 miles per hour.

It is therefore, as above observed, no longer a question whether trains of carriages may be worked by means of atmospheric pressure; the points now to be decided are—

1st. Whether this principle admits of its being advantageously applied to greater distances than half a mile, which is the length of the present experimental line.

2ndly. The probable expense of constructing a railway on this principle, and of supplying the locomotive power.

3rdly. The relative economy in working such a line, as compared with a railway worked by locomotive engines.

4thly. The degree of safety which the atmospheric system affords, as compared with other locomotive means.

In order to answer the first question, it was necessary to institute certain experiments for the purpose of obtaining the necessary data. The detail of these experiments it has been thought best to separate from the Report, and to place in the Appendix, with such deductions as we have been enabled to draw from them. We shall therefore only state here the conclusions at which we have arrived, viz. that this principle of locomotion admits of advantageous extension, and that within certain limits the economy of working by it increases with the length and diameter of the pipe. Thus we have found that while it requires a power represented by 41·4 for a pipe of nine inches in diameter, and half a mile in length, it requires only a power represented by 91 to work a similar pipe of three miles in length, for propelling the same load at the same speed, namely 30 miles per hour. Also, that to work a pipe of 18 inches diameter for the same length, the trains moving at the same speed, but the load being four times greater, requires only a power represented by 184.

There is, however, one important question which we could not satisfactorily settle in consequence of the very imperfect state of the present experimental line, viz. the amount of resistance to the forward motion of the piston in the propelling tube. The apparatus at Wormwood Scrubs has been laid down for nearly two years, and being only worked now and then for an occasional experiment, is not in good order; for the embankment has sustained much injury from the weather, having sunk and slipped in several places, and the propelling tube is in consequence greatly distorted and out of parallelism with the rails. It would have been, therefore unjust to take our data for this resistance from experiments on this line; at the

* See Appendix.

same time, as it is very important that the resistance should be known, we recommend that, before any extensive work is constructed on this principle, proper experiments be made to ascertain what the amount of this resistance may be under favourable circumstances, that is, on a line well formed, in constant operation, and with the rails and tube properly adjusted to parallelism.

If, under such circumstances, this resistance should be found not to exceed 10 per cent. of the whole piston power, as Mr. Samuda states he expects will be the case, it will be much in favour of the economy of this method of working certain lines, particularly those of very frequent traffic.

We now come to the expense of construction.

In the pamphlets circulated by the patentees, credit is taken for two important items which we cannot altogether admit.

First, it is said, that having got rid of the heavy locomotive engine, the rails will admit of a very considerable reduction in weight. We believe that the atmospheric principle will be found to present such great advantage, for the heavy rails which in the progress of the railway system have been introduced into use, have not been adopted solely for the purpose of strength, but also for the sake of the firm and steady bearing they afford, and the consequent easiness of motion and corresponding diminution in the wear and tear of the engine and carriages.

Another questionable item is the estimated reduced expense of cuttings and embankments, it being assumed by the patentees that not having to take the locomotive engine up a plane, much steeper gradients may be introduced than on the present lines. That a great part of the power of a heavy locomotive engine is expended in overcoming its own gravity and resistance in ascending steep planes is certainly true; and it is equally true, that on the atmospheric principle the whole additional force is exerted on the load itself. This is unquestionably an advantage, but still we think its importance has been greatly over-rated.

The patentees propose to work steep inclines by means of larger tubes, but this would involve the necessity of stopping the train at the foot of such planes, and of having again to overcome the inertia of the load; in both instances causing a loss of time.

In respect of locomotive outlay, a line worked by locomotive engines in order to be well stocked should have an engine per mile in addition; this mode of working requires water-stations, engine-houses, repairing-shops, &c. Now we have to place against these the expense of the long vacuum-tube and valve, and the erection of a powerful engine, at every three miles along the road.

With respect to this cost, Mr. Samuda has furnished the following estimate for laying down the atmospheric railway for an extent of three miles on a level plane, and for average loads of 30 tons, to be carried at the rate of 30 miles an hour.

	£.
" Main 12 inches diameter, weighing per yard 2 cwt. 3 qrs. 9 lbs. × 5280 yards = 747 tons 4 cwt. at 7*l*. 10*s*. per ton	5,604
" Planing, drilling, and coating mains, continuous valves, separating ditto, laying mains, and making joints; including all materials and labour on the main and valve, at 1,500*l*. per mile × 3 = ...	4,500
" One engine, station complete, with a 50-horse engine and air-pump erected and attached to the main	2,000
	£ 12,104

" The actual engine-power necessary is 42 horses; we should, however, always propose to fix something more than necessary."

" The estimate is for a single line of way, and is only for the atmospheric apparatus. We presume you are better acquainted with the cost of rails, sleepers, &c. than we are, and did not wish us to furnish it. We should, however, propose to use rails not exceeding 30 lbs. per yard. If the three miles be intended to form an entire railway of itself, *two* engine-stations would be required; if not, one engine-station only will be required every three miles, whatever the length, and one extra, as there must be one at each terminus."

For a double line of rails the cost would be 22,204*l*., or 7,401*l*. per mile.

Mr. Samuda claims a reduction of this amount in consequence of the diminished weight of rails which he proposes to use, but we cannot concur with him in thinking that the rail can be reduced with safety from 75 lbs. to 30 lbs. per yard. We are ready however, to admit that it may be reduced to 56 lbs., and this would

take off 450*l.* per mile from the cost of the permanent way, leaving 6,951*l.* per mile as the excess over the ordinary railway, which might in many cases operate as a bar to the system, for against this sum we could not reasonably put a larger amount than 2,000*l.* per mile for engine-stock, workshops, water-stations, &c.; and we must bear in mind that in many situations it might be difficult to get water in the positions otherwise best suited for establishing the stationary engines for the Atmospheric Railway.

We have now to speak of the relative expenses of working. This is, however, a question to which no general answer can be given, because it depends entirely on the daily amount of traffic. We have no doubt that a stationary engine properly proportioned, according to the rules we have indicated for a pipe three miles long, would be able to work trains on a line every quarter of an hour, or every half hour, each way, during the day (say of 12 hours), amounting to 144 miles. Now to work this distance by a locomotive engine, at the moderate estimate of 1*s.* 4*d.* per mile, would amount to 9*l.* 18*s.*, say 10*l.* per day; whereas the stationary engine power would not cost one half that sum, and consequently a saving in working expenses would arise of 1,800*l.* or 2,000*l.* per annum. But if only half this duty were required, the expenses of the two ways of working would be much nearer equal; and again, if only half the latter duty were to be performed, that is of trains starting only every two hours each way, the advantages would be on the side of the locomotive engine. The fact is, that in one case the expenses per diem will be nearly the same, whether working at intervals of an hour or at every quarter hour; whereas in the other, the charge is nearly proportional to the work actually performed.

In the cost of the maintenance of way there would be a difference in favour of the atmospheric principle.

Our next question is the comparative safety of the two modes of transit.

On this head we may observe, that notwithstanding the accidents which have occurred with locomotive engines, it is a great element of safety that the source of power is always present with the train, and may be almost instantly turned off if any necessity shows itself for stopping, and no doubt very many accidents have been avoided by the engine-driver possessing such power. On the atmospheric principle this is not the case; the source of power is at a distance, as it is in a line worked by rope machinery, and it is with *this* system, therefore, rather than with the locomotive engine system, that the atmospheric principle must be compared. With rope machinery, although the source of power is at a distance, and cannot therefore be stopped by the guard in charge of the train, yet he has the means of instantly detaching the train from that power.

We should have been glad to have seen in this case some similar mode proposed for disengaging the train from the piston. This, however, does not appear to have been intended, but Mr. Samuda thinks it by no means difficult to effect.

The method proposed for throwing off the power at present, is a contrivance which would enable the conductor to open the back of the piston, so that by admitting the air from behind, to produce an equilibrium of pressure, the propelling power would be greatly diminished. But however practicable this may be as a mechanical arrangement, and as a means of regulating the speed, it would certainly not be so instantaneous and effective as a total disengagement; for it would require some time to equalize the air in the tube with that of the external atmosphere, by means of such apertures as it would be possible to open, and during that time, although the area of pressure would be reduced, a certain amount of propelling power would remain active and by so much be mischievous. It is true that, not having to contend with the momentum of the heavy locomotive, the breaks would be more effective, but still this principle will be inferior, in respect of safety, to that of rope machinery, without some contrivance for totally and immediately disconnecting the piston from the trains. We do not apprehend that the piston would be damaged by being thus suddenly let go. It would undoubtedly at first rush forward with great speed, but would thereby compress the air before it, which would ultimately bring it to rest without injury.

Having thus stated the views we entertain on this subject, and having given in the Appendix the experimental results and the investigations on which they are founded, we beg to state,

Firstly. That we consider the principle of atmospheric propulsion to be established, and that the economy of working increases with the length and diameter of the tube.

Secondly. That the expense of the formation of the line in cuttings, embankments, bridges, tunnels, and rails will be very little less than for equal lengths of a railway to be worked by locomotive engines, but that the total cost of the works will be much greater, owing to the expense of providing and laying the atmospheric tube, and erecting the stationary engines.

Thirdly. That the expense of working a line on this principle, on which trains are frequently passing, will be less than working by locomotive engines, and that the saving thus effected will in some cases more than compensate for the additional outlay; but it will be the reverse on lines of unfrequent trains. However, there are many items of expense of which we have no knowledge and can form no opinion, such as the wear and tear of pistons, valves, &c.; on these further experience is needed.

Fourthly. That with proper means of disengaging the train from the piston, in cases of emergency, we consider this principle as regards safety equal to that appertaining to rope machinery. There appear, however, some practical difficulties in regard to junctions, crossings, sidings, and stoppages at road stations, which may make this system of less general application.

We may add that the atmospheric principle seems to us well suited for such a line as the projected extension from Kingstown to Dalkey is represented to be, but we should have been glad if this line had been three miles, instead of only one mile and three-quarters in length, as it would have then brought this principle to a more complete and decided test.

We have the honour to be,
My Lord,
Your Lordship's most obedient, humble servants,

FREDERIC SMITH,
Lt.-Col. R. Engineers, F.R.S.
PETER BARLOW, F.R.S.

APPENDIX.

DETAIL OF THE EXPERIMENTS FROM WHICH ARE OBTAINED THE DATA EMPLOYED IN THE PRECEDING REPORT.

1. In the first experiments no particular record of results was made, except as regards the speed; it will be sufficient therefore to state, that in the cases at which we were present, maximum velocities of 20, 30, and 40 miles per hour were obtained, the greatest load having been 13 tons, and the least about 5 tons—the mean velocity for the whole distance varying from 11·5 to 20 miles per hour.

Dimensions of the Pipe, Pump, and Engine.

The length of the propelling or vacuum tube is half a mile, or 2640 feet, and its diameter 9 inches. The air-pump employed for exhausting the tube is a cylinder of $37\frac{1}{2}$ inches in diameter; length of single stroke $22\frac{1}{2}$ inches, or double stroke 3·75 feet.

The engine employed to work the air-pump is a small boat-engine.

The diameter of piston, $24\frac{1}{2}$ inches.

Length of single stroke, 2 feet, or of double stroke, 4 feet.

The proper number of double strokes per minute, 40; being the dimensions of an engine nominally of 16-horse power.

It was necessary, however, in our case to ascertain its actual power as exhibited at its working point; namely, its actual lifting power after overcoming its own friction and that of the air-pump piston. With this object the carriage was sent to the end of the line, and its piston inserted in the pipe. The carriage being then retained by its break, we ascertained experimentally the number of strokes that were necessary to sustain permanently and steadily different degrees of vacuum, varying from 15 to others of 22 and $23\frac{1}{2}$ inches.

In the first trial the following results were obtained, namely—

A vacuum of	$19\frac{1}{2}$	inches was sustained by	22	strokes per minute.
„	$21\frac{1}{2}$	„	30	„
„	$21\frac{3}{4}$	„	31	„
„	$23\frac{1}{2}$	„	42	„

Second trial.

A vacuum of	$15\frac{1}{2}$	inches was sustained by	14	strokes per minute.
„	16	„	16	„
„	18	„	18	„
„	21	„	$29\frac{1}{2}$	„

Third trial gave precisely the same results.

Having thus determined the number of strokes of the air-pump requisite to support different degrees of vacuum, the next question is to compute the mean pressure per inch on the air-pump piston, when working against these different vacuums. This, by a simple differential operation, is found to be expressed in lbs. by

pressure per inch $= \frac{30-h}{2}$ hyp. log of $\frac{30}{30-h}$, h representing the inches of the vacuum gauge. When $h = 21$ inches, the above formula gives the mean pressure per inch 5·41 lbs. The area of the piston $= \overline{37{\cdot}5}^2 \times {\cdot}7854 = 1104$ square inches. Whence $1104 \times 5{\cdot}41 = 5972$ lbs., total mean piston pressure. This, in our experiments, was overcome at the rate of $29\frac{1}{2}$ double strokes per minute, or at the rate of $29\frac{1}{2} \times 3{\cdot}75 = 110{\cdot}6$ feet per minute.

Hence $\frac{5972 \times 110{\cdot}6}{33{,}000} = 20$ horses'-power.

Although, therefore, the engine is only of the dimensions usually denominated a 16-horse power, it was in this experiment doing the duty of 20 horses' power;

and in other cases, with a higher steam pressure, the duty amounted to 25 or 26 horses.

It is essential that this should be clearly understood, lest any error should arise by confounding this actual effect of the engine with its nominal power of 16 horses.

For the purpose of further comparison between the powers employed in the several preceding experiments, the following mean pressures have been computed for vacuums varying between 10 and 21 inches.

	Inches.		lbs.	Inches.		lbs.
Vacuum	21	pressure per inch	5·41	15	pressure per inch	5·19
,,	20	,,	5·49	14	,,	5·03
,,	19	,,	5·51	13	,,	4·87
,,	18	,,	5·49	12	,,	4·59
,,	17	,,	5·43	11	,,	4·34
,,	16	,,	5·33	10	,,	4·05

By means of these numbers the powers employed in every case, while the vacuum remains constant, is readily determined. As an example, the number of double strokes required to maintain a vacuum of 18 inches was found to be 18 per minute.

Now the pressure per inch for an 18-inch vacuum is 5·49 lbs. per inch; 18 double strokes per minute is $= 3·75 \times 18 = 67·5$ per minute.

Hence $\frac{1104 \times 5·49 \times 67·5}{33,000} = 12·4$ horse-power.

In like manner the power practically employed to maintain any given vacuum may be ascertained by noting the number of strokes made per minute by the engine, and taking the corresponding pressure from the table, without any reference to the nominal power of 16 horses.

Our next object was to ascertain the amount of the lost or absorbed power in producing any required vacuum. With this object we proceeded as below.

The diameter of the vacuum pipe we have seen is 9 inches, and its length half a mile, or 2640 feet.

Its sectional area 63·6 inches.
Capacity . 1166 cubic feet.
The diameter of air-pump, $37\frac{1}{2}$ inches; its length, $22\frac{1}{2}$ inches.
Sectional area 1104 inches.
Capacity . 14·4 cubic feet.

Hence the rato of the receiver to the pump is as 1166 to 14·4, or as 81 to 1; but allowing for junction-pipe, valve spaces, &c., we have estimated that the pump + receiver : pump : : 85 : 1. Therefore the ratio of rarefaction is $\frac{84}{85}$ at each stroke, and consequently, if no leakage took place, the number of strokes necessary to produce a given vacuum, h, that of the atmosphere being 30 inches, is readily found by the well-known formula

$$N = \frac{\log 30 - \log (30-h)}{\log 85 - \log 84}$$

Being thus enabled to determine exactly the number of strokes that would produce a given vacuum, supposing no leakage, we may readily find the amount of lost power by simply counting the strokes practically made to produce the same vacuum.

The following results were thus obtained. The engine was put in motion at its usual speed, and then the pump and receiver were connected:—

First trial.—In	25	strokes,	vacuum =	12	inches.
	40	,,	,,	16	,,
	57	,,	,,	18	,,
	88	,,	,,	20	,,
Second trial.—In	19	,,	,,	10	,,
	26	,,	,,	12	,,
	34	,,	,,	14	,,
	37	,,	,,	15	,,
	44	,,	,,	16	,,
	59	,,	,,	18	,,
	69	,,	,,	19	,,
	83	,,	,,	20	,,

(Time in making 59 strokes, 1 minute 30 seconds). Computing now the number of strokes which would have produced these vacuums, without leakage, we have the

following results, taking the mean of the two trials in the four cases that are comparative :—

Vacuum.	Mean No. of observed double Strokes.	No. of required Strokes without Leakage.	Additional Strokes to supply Leakage.
12	25·5	21 5	4
16	42·0	32·3	10·7
18	58·0	38·7	19·3
20	85·5	46·4	39·1

The discrepancy between the observed number of strokes in the two trials arises principally from the difficulty of determining accurately the time when a given vacuum is produced, in consequence of the oscillation of the mercury in the gauge tube; they are however sufficiently approximative for practical deductions.

To facilitate further comparison, the following table shows the number of double strokes that would be necessary to produce the corresponding vacuum, supposing the pump perfect, and that there was no leakage :—

Vacuums.	Double Strokes.	Vacuums.	Double Strokes.
10 inches.	17·1	16 inches.	32·3
11 „	19·2	17 „	35·3
12 „	21·5	18 „	38·7
13 „	24·0	19 „	42·3
14 „	26·5	20 „	46·4
15 „	29·2	21 „	50·8

In the above experiments the vacuum tube was opened to the receiver when the engine was working at its usual speed; but in one experiment the engine was started from rest, and the times employed in making the vacuum were observed to be,

Vacuum 11 inches, formed in 1 minute 15 seconds.
„ 20 „ 5 „ 0 „

We may here observe that in many trials we found it scarcely practicable to raise the vacuum so high as 20 inches, when the supply of steam was not abundant; a vacuum of 16 or 18 inches could always be obtained very speedily, but beyond that the operation of rising went on very slowly. Now it will be seen in our tabular numbers, page 7, that the piston pressure is greatest at 19 inches; we were induced, therefore, to examine the formula we have given for the pressure to see where the maximum ought to fall.

If we denote $\frac{30}{30-h}$ by y, our formula becomes $\frac{\text{hyp. log. } y}{y}$, which by the method of maxima et minima, gives the fraction a maximum when hyp. log. $y=1$, or when $y=2\cdot718$; but when $\frac{30}{30-h}=2\cdot718$, $h=18\cdot9$ inches, which at once explains what every one observed in the experiments, viz., the extreme slowness of the motion in the rising gauge after having obtained 16 or 17 inches; and proves also the propriety of Mr. Samuda's intention of working with vacuums not exceeding 18 inches.

As the amount of lost power, ascertained by the preceding experiments, was due to the compound leakage of (first) the long valve and joints, and (secondly) of that at the vacuum pipe and air-pump pistons, it became an object, if possible, to separate these effects, because that which appertains to the long valve and joints will increase as the length of the pipe is increased, but the other part will remain constant for all lengths.

With a view to this determination the piston was inserted at the end of the pipe, the carriage to which it was attached being prevented from advancing by its break, the whole pipe thus acting as the receiver or vacuum space; and the number of strokes was noted which were necessary to maintain vacuums of 21, 18, 16, 15½ inches respectively.

The carriage was then moved up the line one-quarter of its length, reducing the vacuum pipe, and of course the long valve leakage, by one-fourth, when similar observations were recorded. The carriage was then moved on so as to reduce the vacuum space and valve leakage one-half, and then to one-quarter, and similar observations recorded. It was, however, found impossible to make the engine go sufficiently slow to obtain the lower vacuums with the short lengths.

B

The following are these experiments:—

Whole Pipe open.

21 inches vacuum	was maintained	with	29½ strokes	per minute.
18	,,	,,	18	,,
16	,,	,,	16	,,
15½	,,	,,	14	,,

Three-fourths Space open.

21 inches vacuum	was maintained	with	24 strokes	per minute.
18	,,	,,	16½	,,
17	,,	,,	14	,,

Half Space open.

21 inches vacuum	was maintained	with	18 strokes	per minute.
19	,,	,,	14	,,

One-quarter Space open.

23 inches vacuum was maintained with 15½ strokes per minute.

The results that we have here, strictly comparative, are the vacuums of 21 inches in the three first cases, the number of strokes being 29½, 24, and 18, and these seem to indicate that about 5½ or 6 strokes per minute were employed in counteracting the constant leakage of the tube and pump pistons; for, reducing the number of strokes made in each case by 5½, we have the following remainders, 24, 18½, 12½, numbers which are nearly proportional to the different lengths of the long valve exposed to leakage.

From the above results we learn that of the whole power employed to supply leakage, about one-fifth part is constant and due to the leakage of the pistons; the other four-fifths are due to the long valve and joints; and for pipes of greater length will increase as those lengths.

The whole number of strokes to support the vacuum of 21 inches on the half mile was 29½, answering to a 20-horse power, of which 4-horse powers are to supply the leakage of the piston, and 16 to supply that of the long valve and joints. Therefore, with the following lengths of pipe, of 9 inches diameter, the expenditure of power would be for—

½ mile	4 + 16 = 20	horse power.
1 ,,	4 + 32 = 36	,,
1½ ,,	4 + 48 = 52	,,
2 ,,	4 + 64 = 68	,,
2½ ,,	4 + 80 = 84	,,
3 ,,	4 + 96 = 100	,,

With the vacuum 18 inches, the number of strokes was 18, and the horse powers about 12·4, of which one-fifth, viz., 2·48, were constant and 9·92 variable, so that the power required for—

½ mile is	2·48 + 9·92 = 12·40
1 ,,	2·48 + 19·84 = 22·32
1½ ,,	2·48 + 29·76 = 32·24
2 ,,	2·48 + 39·68 = 42·16
2½ ,,	2·48 + 49·60 = 52·08
3 ,,	2·48 + 59·52 = 62·00

In tubes of larger diameter we may consider the leakage of the long valve for the same lengths to be the same as above, but the piston leakage will be proportional to the diameter.

Experiments on the Speeds obtained with different Vacuums.

The piston pressure per inch on the air-pump is nearly the same for all vacuums from 21 inches to 17 inches, that part of the power of the engine which is engaged in discharging the tube as the train advances, is also nearly the same in all these cases; while the lost power, by leakage, is less as the vacuum is reduced,

as is also the piston pressure in the tube. We were desirous therefore, if possible to ascertain the working force which different vacuums possessed of urging the train forward, but we failed of obtaining on this part of our inquiry any useful results, the engine not having sufficient power to preserve the vacuums constant. We commenced with pressures of 20½ inches, then 18 inches, then 16 inches, but in all these experiments, except the last, the vacuums were reduced to about 12 or 14 inches towards the end of the trip, instead of remaining the same as at the beginning, or of rising higher. We were unable, therefore, to deduce from them any confirmatory evidence; it may, however, be proper to record them.

First Experiment.

Vacuum at the commencement . .	20½ inches.
Time of passing the whole distance .	1 m. 40 sec.
Total number of double strokes . . .	53.
Mean number per minute	31·8.
Mean speed per hour	18 miles.
Maximum speed during the experiment	20 „
Vacuum towards the last	12 inches.

Second Experiment.

Vacuum at the commencement . . .	18 inches.
Time of passing the whole distance .	1 m. 55 sec.
Total number of double strokes . . .	60.
Mean number per minute	31·3.
Mean speed per hour	15·8 miles.
Maximum speed during the experiment	17·6 „
Vacuum towards the last	14 inches.

Third Experiment

(Being the 1st repeated).

Vacuum at the commencement . . .	20½ inches.
Time of passing the whole distance .	1 m. 46 sec.
Total number of double strokes . . .	61.
Mean number per minute	34·5.
Mean speed per hour	17 miles.
Maximum speed during the experiment	20 „
Vacuum towards the last	14 inches.

Fourth Experiment.

Vacuum at the commencement	16 inches.
Time of passing the whole distance	2 m. 32 s
Total number of double strokes	74
Mean number per minute	29·2
Mean speed per hour	11·2 miles.
Maximum speed during the experiments . .	20 miles.

Note.—This maximum speed was towards the end. It was but 13 miles at the usual place of maximum, the vacuum towards the last was omitted to be noted in this experiment.

No conclusions can be drawn from these four experiments, except that, by the falling of the vacuum, it is clear that, with all the force thrown upon the engine, it was inadequate to the duty it had to perform.

Other experiments or rather observations were made on the time in which the vacuums fell inch by inch, from leakage only, the engine being at rest, and the whole length of pipe exposed to leakage; of which it will be sufficient to record the following.

The height of vacuum gauge being 21 inches,—

In one minute it fell	4½	inches, viz., to	16½ inches.
In the second „	4	„	12½ „
In the third „	3½	„	9 „

Deductions from the preceding Experiments.

It has been seen that the air-pump is about one 85th part of the whole vacuum space; and this vacuum space has to be discharged of its air by the air-pump, while the carriage is passing over the line. At 30 miles an hour, the half mile must be passed in one minute; therefore the pump must make about 41 or 42 double strokes in the minute, equivalent to about a 29-horse power, besides which we must have a sufficient leakage-discharging power for the whole length, although that power will be in excess after the carriages have advanced a short distance, and will be more and more in excess as the train advances.

The actual lost power by leakage is indeed only half that necessary to support the entire length for the time the train is passing, but it is difficult to take advantage of this circumstance; we have seen that when the carriage is at rest at the end of the line, there is a loss of four inches in a minute in the vacuum; if therefore only half the leakage-discharging power were provided, the vacuum would fall at first nearly two inches per minute, and therefore on a line three miles in length, it would be greatly reduced by the time the train had reached the middle of the line, and the consequence must be, that the first half of the line would be passed very slowly, and that the latter half must be passed with great velocity, in order to obtain the mean speed of 30 miles per hour, which irregularities are objectionable. Some saving however might be effected by employing the whole power of the engine to raise the vacuum, before starting, two or three inches above the intended, working vacuum; but we shall not attempt to estimate the value of this and other practical advantages that may probably be introduced. We must, as the experiment at present stands, assume that the leakage discharging power for the whole length must be provided. This, as we have seen, consists of two parts, the one constant, viz., that due to the pistons, and the other variable, as depending on the length of the tube, viz., the leakage at the joints and at the long valve.

The amount of this leakage power for different lengths is given in pages 9 and 10, and adding to this, the constant discharging power at 30 miles per hour, we find the whole power required, for the following different single lengths of pipe of nine inches diameter, at the above speed, to be—with a vacuum of 21 inches—

½ mile	49 horse power.	2 miles	97 horse power.
1 ,,	65 ,,	2½ ,,	113 ,,
1½ ,,	81 ,,	3 ,,	129 ,,

With a vacuum of 18 inches at the same speed,—

½ mile	41·40 horse power.	2 miles	71·16 horse power.
1 ,,	51·32 ,,	2½ ,,	81·08 ,,
1½ ,,	61·24 ,,	3 ,,	91·0 ,,

The pressures in these two cases, taking the piston surface at 63 inches, will be in the first 661 lbs., and in the second 567 lbs.

To render the pressure with the latter vacuum equal to the former, the tube must be increased from 9 inches to 9·7 inches, and the discharging power increased from 29-horse power to 34-horse power. So that in this case the required powers would be—

With a vacuum 18 inches, diameter of tube 9·7 inches.

½ mile	46·40 horse power.	2 miles	76·16 horse power.
1 ,,	56·32 ,,	2½ ,,	86·08 ,,
1½ ,,	66·24 ,,	3 ,,	96·0 ,,

From these results we may draw some important conclusions, viz., that to work three miles of pipe requires little more than double the power requisite to work half a mile, and that the lower vacuum is worked considerably cheaper than the higher; the higher or 21-inch vacuum requiring 129-horse power to effect precisely the same duty as is performed by 96 horses with an 18-inch vacuum.

It will also be seen that a larger pipe is much more economically worked than a smaller one. A pipe nine inches diameter and three miles long requires, as we have seen, 91-horse power, when the vacuum is 18 inches. Whereas a tube of 18 inches would require only 184-horse power, viz., for discharging 116 horses, for piston leakage 6 horses, for long valve and joint leakage 62 horses.* So that,

* It may perhaps be questioned whether the joint leakage will be the same for large and small pipes; if it should be greater, some further power than 62 horses would be required.

with little more than double the power, four times the amount of piston pressure may be obtained.

It appears therefore that the economy of working increases at every point as we increase the scale of our operations.

The next question is the time that will be necessary to obtain a given vacuum in pipes of great lengths, as, for example, three miles.

We have seen that the time of forming a vacuum of 18 inches in a pipe 9 inches diameter, and half a mile long, required one minute and a half: that the number of strokes was 58; and that the number that would have produced this vacuum, had there been no leakage, would have only been 38·7, showing a lost power therefore of 50 per cent.; the ratio of the pump space to the whole vacuum space being in this case as 1 to 85, and the power of the engine at the working point about 25 horses.

Now for the three mile pipe, the proposed engine power is 91 horses; therefore increasing the pump space in the ratio of 25 to 91, and the whole vacuum space as half a mile to three miles, or as 1 to 6, the ratio of rarefaction is found to be $\frac{139}{140}$, and the number of strokes, supposing no leakage, would be—

$$N=\frac{\log 30-\log(30-h)}{\log 140-\log 139}=128$$

to which adding 50 per cent. for lost power, gives the total number of strokes 192; and then as 58 : 192 so is one minute and a half to 4 minutes 58 seconds, the time requisite to form the vacuum in a pipe nine inches diameter and three miles in length.

By a like process, we find the time that would be necessary to obtain the same vacuum in a pipe of 18 inches diameter and three miles long, with the power of 184 horses, to be about 10 minutes.

For the convenience of calculation we have assumed the same length of stroke in the larger engine as in the smaller. Of course this would not be the case, but the speed of the piston per minute would be about the same, and the difference on this account therefore would not materially affect the final result.

We have already stated that the unit of our horse-power is 33,000 lbs. raised one foot in a minute, and that our numbers must not be confounded with the nominal power of the engine as estimated in the usual way by the diameter of the cylinder and length of stroke. Every such nominal horse-power may be considered as capable of raising 58,000 lbs. one foot in a minute, and, after deduction for the friction of the air-pump, of still exhibiting at the working point 52,000 lbs.; consequently all our numbers require to be reduced in the proportion of 52 to 33 to obtain from them the nominal horse-power requisite for producing any of the above results.

The next and last question connected with this part of the inquiry is the resistance opposed by the friction of the piston, and of the apparatus for opening and closing the long valve. The preceding investigations will enable us to determine the pressure per inch, and consequently the whole pressure upon the tube piston, with any proposed diameter of pipe, with any vacuum, and for any proposed speed; but it is obvious that only so much of this pressure will be effective as remains after overcoming the resistance above referred to.

This resistance, as exhibited by the apparatus at Wormwood Scrubs, is very considerable; so great, indeed, that unless a large portion of it is due to the imperfections of the line, it is such as would render any useful application of this principle rather questionable; but we are disposed to attribute a great part of it to the circumstances under which the experiments are at present made.

The apparatus has been erected nearly two years, with only now and then an occasional experiment; the embankment has suffered much from the weather, and the propelling tube itself is greatly bent and distorted by the sinking of the bank, so that there can be no question that this resistance would be much less on a well-formed line in constant operation; but what would be its actual amount we have no means of judging. We would recommend, therefore, before any extensive work on this principle be undertaken, that proper and sufficient experiments should be made to ascertain, as nearly as possible, what this resistance would be under more favourable circumstances. We may remark here, that whatever this resistance may be in any case, it will be proportionally less as compared with the pressure, as the diameter of the tube is increased; the one increasing simply as the diameter of the pipe, and the other as its sectional area.

Additional Experiments.

After the foregoing pages were written, Mr. Samuda adjusted three of the pipes, so as to bring them nearly level and parallel to the rails, in order to ascertain, as far as is practicable, the amount of the piston friction ; and, as nearly as could be determined, it appeared to be about 10 per cent. of the whole pressure, with vacuums of from 2 to 14 inches. But not only is the line in a very dilapidated state, but the carriage itself is in bad order, exhibiting a friction amounting to 14 or 15 lbs. per ton, whereas it ought not to show more than about 6 lbs. per ton; we cannot, therefore, consider these particular results as conclusive.

Subsequent experiments were also made in reference to the proportion of lost power to be assigned to the piston leakage and that of the long valve. Mr. Samuda has been accustomed to allow more for the former and less for the latter than we have deduced from our experiments, and as this subdivision of the total lost power between the constant and variable parts is an important point in this inquiry, we appointed another day for a repetition of those experiments; but the results confirmed our previous deductions.

We have attributed one-fifth of the total lost power on the half mile to the piston, and the other four-fifths to the long valve and joints, and similar results were obtained on this occasion. We found, for instance, that the vacuum of 21 inches on the whole length was sustained by 25 strokes per minute, and by 20 strokes on three-fourths the length, which, after deducting 5 (one-fifth of the greater) from both, the remainders, 20 and 15, are proportional to the lengths, viz., 4 to 3.

The 19-inch vacuum for the whole length was supported by 20 strokes, and on three-fourths the length by 15·75, which, after being reduced by one-fifth of the greater, leave for remainders 16 and 11·75, also nearly as 4 to 3.

The 18-inch vacuum for the whole length was sustained by 18 strokes, and on three-fourths the length by 14·5, which, being reduced as above, again leave remainders, which are nearly as 4 to 3.

The 21-inch vacuum for the half-length was noted at 16·8 strokes, which shows a discrepance from the above law; but in this case the engine varied greatly in its speed during the time.

When its motion was most uniform, we noted 30 strokes for two minutes, which agrees exactly with the law above stated.

As another test we made an experiment by withdrawing the piston, and inserting a tight plug in the end of the pipe, well luted with tallow to prevent any leakage at that part, and we then found the vacuum of 21 inches sustained with $20\frac{1}{4}$ strokes per minute, which shows again a leakage amounting to about one-fifth at the piston. This experiment seems also to prove that the air-pump piston leakage is very inconsiderable. There appears, therefore, to be no ground for making any change in our former division of the lost power, as to the portion of it which belongs to the constant and that which appertains to the variable leakage. We have been the more particular in illustrating this point, because upon it depends the amount of power that ought to be provided for lines of greater lengths than half a mile, and consequently the economy of this principle of working as compared with other locomotive means.

LETTER FROM MR. PIM TO THE EARL OF RIPON.

My Lord,

I beg leave, through the medium of your Lordship, to submit to the consideration of the Lords of the Committee of Privy Council for Trade, the following communication respecting the system of locomotion on railways, by means of the pressure of the atmosphere, which the inventors have called " The Atmospheric Railway."

The institution of a special department of the Board of Trade for the surveillance, and, to a certain extent, for the control of railways, will, I hope, be considered sufficient justification for trespassing on their Lordships.

If the proposal I am about to submit had no further object than to lessen the present expenses in the construction, maintenance, and working of railways, I would respectfully urge that it is well entitled to the attention of your Lordship; since, to use the words of an enlightened and intelligent writer on these subjects, " in all countries and under all circumstances, it is an object worthy of a statesman, to prevent a waste of the national means, and to give a right direction to the public expenditure." If, in addition to economy, the proposal went to obtain considerably greater speed of travelling with increased comfort to the passengers, it would have still stronger claims to favourable consideration; but if, besides these advantages, it is proposed to remove from the railway system almost all its liability to accident, and to confer on it almost absolute exemption from danger, combining in itself all the great desiderata of railway transit, safety and comfort being closely bound up with economy and expedition, I have no hesitation in claiming that it is entitled to rank with the most important inventions of the present age, and I am confident it will not fail to obtain from your Lordship and the Board of Trade, the attention and inquiry it deserves at your hands, as conservators of the public safety.

This claim is not made lightly, nor without a suitable feeling of responsibility; it has resulted from a careful and prolonged investigation, and from repeated experiments, in which I have been assisted by many of the most distinguished men of science, and by several eminent practical engineers, whose concurrent opinions have led me to such a perfect conviction of the importance of the subject, as to induce this application to your Lordship.

I will commence my statement with a concise description of the means by which the objects I have enumerated are obtained, and will then state, in some degree of detail, the advantages offered by the proposed plan, which will necessarily lead to some comparison with the present system; and I shall beg to ask your Lordship's kind attention to the suggestion I shall, in conclusion, venture to offer, as the means of obtaining some useful result.

It is very generally known that several ingenious persons have, from time to time, proposed to employ the pressure of the atmosphere, as an element of locomotive power; but their speculations and suggestions were so far removed from practical efficiency, that proposals to adopt an atmospheric or pneumatic railway have hitherto been received with contempt or ridicule; indeed, so great has been the prejudice against the principle, that very few, even among those most interested in railways, have taken the trouble of investigating what has been accomplished by the very simple and complete apparatus constructed by Messrs. Clegg and Samuda, whose invention has been publicly exhibited on the West London Railway, at Wormwood Scrubs, for nearly 18 months past.

Although the scale upon which these experiments have been tried, may be thought scarcely sufficient to arrive at an absolute demonstration, by those who only view it superficially, every successive visit has tended to confirm the conviction in the minds of those best qualified to decide, that the invention combines the great essentials of *economy*, *expedition*, and, above all, of *safety*.

On this system of working railways, the moving power is communicated to the trains by means of a continuous pipe or main, of suitable diameter, laid in the middle of the track, and supported by the same cross-sleepers to which the chairs and rails are attached; the internal surface of the pipe being properly prepared by a coating of tallow, a travelling piston made air-tight by leather packing, is introduced therein, and is connected to the leading carriage of each train by an iron plate or coulter. In this position, if part of the air be withdrawn from that length of pipe in front of the piston by an air-pump, worked from a stationary engine or by other mechanical means, placed at a suitable distance, a certain amount of pressure on the back of the piston (being the locomotive force) will take place, proportioned to the power employed; in practice, and to work economically, it will be sufficient to produce an exhaustion of air in the pipe, equal to causing a pressure from the atmosphere, upon or behind the travelling piston, of 8 lbs. per square inch, which is only about one-half the pressure due to a vacuum. Supposing the main pipe to be of 18 inches internal diameter, it will receive a piston of 254 superficial inches area, on which, with the above pressure, a tractive force of 2,032 lbs. is consequently obtained; and this is capable of propelling a train weighing 45 tons (or eight to nine loaded carriages), at the rate of 30 miles an hour, up an acclivity of 1 in 100, or 53 feet per mile.

The iron coulter being fixed to the travelling piston within the pipe, and also to the leading carriage of the train, connects them together, moving through an aperture formed in the top,

and along the whole length of the pipe; while one set of vertical rollers attached to the piston-rod, at some little distance behind the piston, progressively lift up for the space of a few feet, and another set of rollers attached to the carriage close down again, a portion of a continuous flexible valve or flap, of peculiar construction, covering the aperture; and it is the very simple, ingenious, and efficient mode of successively opening, and closing down and hermetically sealing this valve, as each train advances and moves on, that constitutes the merit of the invention, and the foundation of the patent; the operation consisting first, in opening the valve to admit the free admission of the external air, to press on the back of the piston, and produce motion; and then in effectually closing down and sealing the valve again, so as to leave the pipe in a fit state to receive the travelling piston of the next train, and ready to be again exhausted of its air.

Stationary engines of sufficient power, proportioned to the amount of traffic and speed required, would, in practice, be placed at intervals of about three miles apart, and be arranged to work the railway to that length, alternately on either side of their position, as might be required.

I have not attempted to go into a more detailed explanation of this simple mechanism, nor of the mode in which the main or pipe may be divided, by "separating, exit, and entrance valves," which do not offer any difficulty either in construction or use, into suitable and convenient lengths for exhaustion, in such manner as to allow the passage of the train from one length into another, with any degree of velocity; these, and all the other minutiæ will be best understood, by those who may be desirous of entering into them, from a visit to Wormwood Scrubs.

It may be sufficient here to observe, that the composition for sealing the valve has stood the effect of exposure to the seasons and of continued use for nearly 18 months; that the tallow lining of the pipe produces a smoothness over its interior infinitely cheaper, and probably more effectual, that the most finished boring; and that the connexion of the piston in the pipe, with the train, will be readily comprehended by any one who will examine a pencil moving in an ordinary pencil-case.

When it becomes necessary to stop or retard the carriages, in addition to the use of a common break, a valve in the travelling piston may be opened by the guard or conductor of the train, whereby, the external air being admitted in advance of the piston into the exhausted portion of the pipe, the propelling power is at once destroyed.

The separating valves, in the main or pipe between each section or division of the line, being made self-acting, there will be no occasion for stopping, or even for retarding the movement of the train, in passing from one division of the pipe to another, as the air is successively exhausted by the stationary power, placed at the proper intervals; the carriages may, therefore, pass continuously, at any required velocity, as if drawn by a locomotive engine; and it is necessary to keep this circumstance in mind, as by any other system of traction by stationary engines, than the atmospheric, a stoppage and a change at each engine is unavoidable.

All written descriptions of mechanical arrangements tend to produce on the minds of those not well acquainted with such details an impression of the existence of much greater complexity than is really found; one inspection, however, of the apparatus at Wormwood Scrubs will convince any inquirer how extremely simple it is, and how very little liable to get out of order; that those parts which have a tendency to wear can be easily and cheaply replaced; and that the comparison is strikingly favourable to the proposed system of working as contrasted with the locomotive engine, where all the complex details are crowded into the smallest possible space, where a considerable portion is necessarily exposed to the effects of an extremely high temperature, the several parts loaded with the strain of the whole force of the steam, moving with great rapidity among themselves, and where the whole machine generating the motion is itself impelled along with the mass at a high velocity.

The great feature of the modern system of railway traffic is this locomotive steam-engine; and nothing is, perhaps, better calculated to demonstrate the mechanical genius of the country than the successive improvements which have been applied in the details of its construction. While our engineers have gradually ventured to lay out railways deviating greatly from the truly horizontal lines, originally considered nearly indispensable, and have increased the velocity of the trains to an extent almost alarming, the skill of the mechanist has kept pace with the necessity of finding powers to do the duty required; and by dint of strict regulation of the expenditure, and various minor improvements, the cost of locomotive power has certainly decreased, when calculated upon a mere mileage of the trains. But as the gradients of railways have been made steep, and as the rate of travelling has been augmented, the engines have of necessity been made of greater power and weight, and additional sources of danger created by the introduction of assistant locomotives to surmount inclines, or to keep up high speeds, and by the necessary increased momentum of the trains.

With all the recent improvements and saving in the cost of locomotive power, the wear and tear, as compared with stationary power, is, however, fully 20 to 1, as may be exemplified in many instances of stationary engines working 10 or 12 years without any material repairs, and scarcely without stopping, and contrasting this with the costly establishments and constant expenditure incurred, even on short lines of railway, in keeping up locomotive engines to their effective performances.

In addition to the causes of damage and expense from the use of this travelling power, there are the delays incident to the slipping of the engine-wheels from the want of adhesion when the trains are heavy, or the gradient steep, or the rails "greasy" from slight rain, or glazed by fog or hoar frost, and again by the freezing of the pumps in severe wintry weather; each of which causes of delay becomes an additional source of danger, from which repeated and serious accidents, attended with fatal results, have happened. Although the occurrence

of the pumps freezing is not frequent in this country, yet in many parts of northern Europe and America it must almost act as a total stoppage to railway traffic with locomotive engines in the depth of winter. The variation in the rate of travelling, from the varying velocities of trains drawn by locomotive engines, is likewise a cause from which accidents occur; and yet these different rates of speed can scarcely be avoided, as third-class passengers and luggage, to be economically transported, must necessarily go by slower trains.

To these various disadvantages in working with locomotive power may be added the necessity of using coke almost exclusively, which, in remote districts particularly, adds enormously to the expense. Fixed engines, consuming coal or turf, (and, on the continent of Europe and in America, wood,) as the case may be, will give out steam-power at a greatly less cost than locomotives can do under the most favourable circumstances. But besides the wear and tear of the locomotive engine, and its injurious effects on the railway, there are some other striking disadvantages connected with it: a very considerable proportion of its power is manifestly absorbed in moving its own weight and that of its tender; while it is equally obvious that the faster it travels, and the further the gradient deviates from a horizontal line, the more power is thus absorbed; but few persons are aware that this loss takes place in a rapidly increasing proportion, not only arising from the causes I have stated, but from others which are inherent in the construction of the machine; so much so, that it is stated by Mr. Wood, in the last edition of his work on Railways, that, under ordinary circumstances, increasing the velocity of a train from 25 to 30 miles per hour is attended with a loss of more than half the effective power of the engine. A similar loss is sustained if the locomotive has to draw its load up an incline scarcely perceptible to the unpractised eye; and, should this inclination be increased to 1 in 100, the effect is reduced to about one-fourth of that produced on a horizontal plane at the previous velocity, the power being lost or absorbed in the inverse ratio in which it requires to be augmented, precisely at the moment when it is most important to obtain an increase. This subject has been ably treated in the Second Report of the Irish Railway Commissioners, (see notes D and E, pp. 104 to 110, which are understood to be from the pen of Professor Barlow.) It is there shown that "the power thus absorbed, in what may be termed the preparation for motion, with first-class locomotives, is 1,075 lbs., which is sufficient to draw more than 14 tons on a good road by horse power," "and on a canal, with the usual barges," "more than 190 tons," and that "this absorbed power is nearly one-third of the whole power of the engine." Now the great advantage of the atmospheric system will be to obviate the waste of power, and consequent absorption of profits, arising from transporting useless weight and overcoming unnecessary friction, which it is hopeless to succeed in effecting by any other known mechanical means;* for, as it is proposed to work on this system, there will be nearly obtained a corresponding dynamic effect for the amount of power generated, whatever it may be; whilst, by the present system, as I have already shown, there is an enormous absorption of power by the locomotive, whether moving at high rates of velocity, or up any material acclivities.

It is manifest that on railways intended to be worked by atmospheric power, there is not at all the same necessity for having "good gradients," as on those now at work; and wherever it may be necessary to adopt rather steep inclines for some short distance, it can easily be accomplished by increasing, at the place of difficulty, the dimensions of the apparatus and the amount of mechanical power.

If then, by the proposed means, steep rates of inclination may be overcome without any further difficulty than that of supplying a proportionate increase of power, at its proportionate cost, it is clear that the savings in earth-work, bridging, road-approaches, rails, curves, and other points of expense in construction will follow of course; from the small height required for the carriages, the road may generally be so concealed as to be very much less objectionable in comparatively private grounds; and various other sources of considerable expense may manifestly be obviated. Thus facilities will be afforded for the profitable introduction of railways into districts which would be almost impermeable by the present means.

The economical advantages of the atmospheric system will be further exemplified in the diminution of the expense of maintenance. The destructive action of the locomotive engine (seldom, with its complement of water and fuel, of less weight than 15, and often nearer to 20 tons) no longer impinging on the rails, a comparatively small sum will keep the line in repair; and though it may be difficult beforehand to assign the exact proportion of saving, it is evident the amount must be very considerable.

In the carrying department the whole of the water stations, repairing shops, and fittings up, necessary for the locomotive engines, are at once dispensed with, and the coverings and general arrangements of all stations much diminished in cost; heavy turnplates may be wholly done away with, and even the smaller ones, except at the termini of great lines, as the carriages can move in either direction; every description of carriage, having no longer to sustain the shock and tug of the locomotive, may be made very much lighter and cheaper, and built to carry a greater useful load both of goods and passengers in proportion to the weight, than is the case at present, and will last considerably longer.

---

* The patentees have illustrated this by supposing, for the sake of argument, the expense of maintaining and working the London and Birmingham Railway to remain *unaltered*, but, by the adoption of some other mode of obtaining power, that the necessity of carrying the weight of the locomotive engine and tender (20 tons) with each train was obviated, that weight being perfectly useless. It is clear that the Company would then be able to transport with each train, for the same cost as at present, 20 tons gross, say 15 tons net, of profitable merchandize additional, which (at the lowest charge for goods along the whole 112 miles, viz., £2 per ton), would add to the revenue £30 per journey, or with the present number of trains (12 in each direction every working day), about £225,000 a year, equal to an additional dividend of 5 per cent. to the subscribers.

The rate of travelling by the atmospheric railway will depend on the rate at which the air in front of the piston may continue to be pumped out by the engine, a sufficient degree of exhaustion having been previously obtained to move the load at the required velocity: and I see no reason to doubt that a speed of 60 miles per hour may be easily, economically, and safely obtained by this means; and in addition the passengers will be relieved from the noise, smell, dust, sparks, and hot cinders from the locomotive engine.

A moment's inspection of the apparatus, or a little consideration of the description, will be sufficient to produce the conviction that the pressure of the atmosphere cannot move two trains at the same time in opposite directions between any two stationary engines, and thus collision becomes impossible on the atmospheric railway. It is equally obvious that one train cannot overtake another, and the leading carriage of each train being firmly attached to the piston-rod, it is scarcely possible that a carriage can be driven off the rails. Thus the ordinary sources of railway accidents appear to me to be removed, and the apprehension of danger now unfortunately so general, would soon naturally subside on the introduction of this principle into practice.

It becomes manifest from the preceding statements, that by the proposed means single lines of railway may be worked with perfect safety; there are but few districts of country through which, by starting trains with sufficient frequency, a single line of railway would not be adequate for all their present or prospective traffic, even with the use of locomotive engines; but single lines cannot be worked by these machines without incurring that risk of collision which will render the practice highly objectionable, and will always prevent the use of such lines to their full extent or capabilities.

The atmospheric principle is free from this objection, and single lines can be worked thereby fully and effectively. Trains may be despatched from each end of any line in opposite directions, as frequently as the traffic may demand, without the possibility of coming into collision; as it has been already shown that no trains in motion can possibly approach nearer to each other than one section of the main pipe, being at the least three miles. Sidings would of course be provided at every station.

In first construction the economy will be very great, where the railway shall be laid out originally to be worked on the atmospheric principle; first, the saving on the longitudinal section, arising from the system of gradients which may now be adopted; next, the consequent saving in transverse section, further increased by the certain assurance that single lines may be almost universally introduced without any apprehension of danger; the cost may be likewise materially lessened by introducing curves of much shorter radii than on ordinary railways; the rails may be reduced to a weight little above a third of that now generally adopted, and the expenditure on the remainder of the "upper works" be greatly economised. Nor is this all: where bridges or viaducts have to be built over roads, ravines, or rivers to carry the railway, very light and inexpensive structures may be substituted for the hitherto costly erections, in such cases necessary to sustain the weight and action of the locomotive engines. And where the line has to pass below roads or canals, or through tunnels, the height of the arch may be made much lower than at present, eight feet in height, allowing sufficient space to clear the tops of the carriages; and in every place this will form a vast economy, which will be well and readily appreciated by the engineer. A few sections and diagrams illustrating the difference in some of the works necessary to be executed on the present and on the proposed plan, will probably be sufficient to bring this part of the subject forcibly before your Lordship. Some of these illustrations, however, embrace extreme cases.

With stationary engines placed at intervals of say three miles, there may be at those distances, under judicious management, a large amount of spare power to be employed for many useful purposes. At times between the passing of the trains, when the engine would not be required to work the air-pump in exhausting the pipe, it might grind oats or wheat, saw wood or stone, pump-water, drain lands in one part or irrigate them in another, thus performing various mechanical or agricultural operations; in suitable situations a smaller engine might be continually employed, in lieu of the larger one, in raising water to a proper reservoir, where it would be always ready and available as the trains might arrive, being equally applicable as steam to work the air-pump. All the contrivances for the economic generation and use of steam, such as clothing the boiler and working by expansion, are available to the fullest extent with the stationary engine, which is not the case with the locomotive. In some places the natural supplies of water might even be accumulated in sufficient quantity to dispense with the steam-engine altogether.

What the ultimate result would be of having a large amount of steam power,* which may be hired out on most reasonable terms for various useful purposes, spread over the face of the country at intervals of three miles, and having a railway communication with each of them, I shall not now stop to inquire; but I submit it as an interesting and peculiar feature of the proposed plan, and one eminently deserving your Lordship's attention.

As it is practicable by the introduction of the atmospheric system to reduce the cost of constructing, maintaining and working railways so materially, a corresponding reduction in the charges for transmission of goods and passengers will follow; if, in addition, we are enabled to carry passengers at considerably greater speed and with much greater comfort, and, above all, if we are able to remove the apprehension of personal danger, who is there bold enough to assign the limit to the advantages of railway intercourse by this means?

It may, perhaps, not be unnecessary to anticipate the very natural inquiry, why this in-

* In round numbers, upon the present and proposed Railway lines throughout the United Kingdom, this power would be equal in the aggregate to about that of 100,000 horses, and available for probably eight hours out of every twelve, should advantage be taken of it.

vention, possessing all the advantages I have endeavoured to enumerate, has not yet been adopted by some of the enterprising parties engaged in railway speculations, or to explain why the patentees themselves have not brought it out in a sphere of more extended operations.

The explanation is easy, and the answer to the inquiry simple. An experimental apparatus, in the hands and under the sole management of the patentees, will never satisfy the public. I submit, however, that they have already done more than enough in demonstrating the principle and practice of their invention, to have induced spirited parties to have taken the matter up, were it not for the great amount of prejudice, arising chiefly from the abortive attempts of those who have hitherto trifled with this great principle of power. Independent of the extraordinary depression of speculative enterprise at the present moment, and which a variety of causes seem likely to retain in that state for some time to come, it is scarcely to be expected that those who are so deeply interested in the numerous railways already constructed and in operation, whether as directors, shareholders, or engineers, should feel any desire to develope the capabilities of a new system, which may become the means of creating formidable rival lines. This will be better understood when I explain that, from causes which it is not now necessary to go into, the great direct line of railways connecting Liverpool and Manchester with the metropolis, have alone involved an expenditure of nine millions sterling; and that the annual receipts are about one and a half millions, of which nearly 50 per cent. is absorbed in the expenses of working and maintenance.

The satisfactory solution in the eyes of the public of the atmospheric system, reduced to practical usefulness, could not be long without producing results, that would materially strike at the root of the monopoly which these great lines possess, and which has been often complained of.

It can be readily shown that the same extent of railways, connecting the above important places, might be made, on the atmospheric principle, at about one-third of the above cost; and when completed, might be worked at nearly a proportionate reduction on the present gross charges; thereby ensuring a corresponding diminution of expenses to travellers, while affording, as has been explained, greater comfort, safety and expedition.

However much, therefore, the public would benefit from the success of this invention, it is evident the numerous persons connected with railway establishments, even if they were as thoroughly convinced as I am of the accuracy of what I now set forward, are the last persons to be expected to encourage the patentees, or to try the experiment.

Again, no railway at full work could even make a trial of it, without most materially interfering with their existing traffic; and, it may be doubted whether the funds of any Company could, with strict legal propriety, be appropriated to the undertaking of such an experiment except upon their own line. The conducting of any further inquiries to test the merits, or to discover the practical disadvantages, if any exist, of the atmospheric railway, on which are to depend the adoption or rejection of this ingenious application, must therefore be undertaken by parties whose science, station, and character will, by an unbiased report, stamp that value on the invention which it ought to receive, should it be found to merit such approbation; and it is only from the Railway Department of the Board of Trade that the first steps to forward such an inquiry and report can emanate.

This, my Lord, is my statement; and I respectfully submit that I have established a case for further inquiry; to facilitate which, I am authorised by the patentees to state, that the present apparatus on the West London Railway, and the means of working and experimenting, shall be most unreservedly placed at the disposal of the Board of Trade and its officers; and that all drawings, specifications, calculations, and other information shall be furnished, which may be considered necessary to give proper and full explanations.

May I, therefore, beg your Lordship, in your official capacity as President of Her Majesty's Board of Trade and Plantations, to submit this letter to your Right Honourable Board, accompanied by my respectful but earnest request, that they may be pleased to refer it to such persons as their Lordships may select, *to inquire into the several statements herein contained,* and to report to your Lordships *fully* thereon, and *particularly,* whether this invention is entitled to a further and more extended trial, under suitable superintendence; and that your Lordships may also make such other and further orders in the premises, as the important interests herewith connected may appear to your Lordships to demand.

I have, &c.,

JAMES PIM, Jun.,

Treasurer of the Dublin and Kingstown Railway Company.

Earl of Ripon,
&c. &c.

London: Printed by WILLIAM CLOWES and SONS, Stamford Street,
for Her Majesty's Stationery Office.